PM Work Group Discussion Topics, 11/16/20 call on tunnel mixing issues.

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Assume tunnel flows are at least 500 cfm for this discussion. Diagrams of the ASTM 2515 tunnel are included at the end of this list.

1a. The ASTM 2515 dilution tunnel has mixing issues despite Reynolds #s >50,000 in the vertical sampling section (usually 6 to 8" diameter), described as follows: <<The dilution tunnel diameter shall be sized such that the flow velocity … shall result in a minimum of 4.1 m/sec (800 ft/min)>> This velocity minimum may be needed for the pitot tubes used for tunnel flow measurements and velocity traverses.

1b. The method does not rely solely on the turbulence in 1a. for mixing; it has a section labeled "Mixing" – the horizontal run between the hood and the down-section where sampling is done as shown in the detail drawing below. However, there are no dimensions for this mixing section – no diameter, no length, no velocity, no residence time. Requiring this section to be larger might be part of a solution – a longer horizontal run with at least 12 in. diameter.

2. How could the ASTM tunnel be modified to improve mixing?

(a). Is longer residence time / lower velocity needed in the final vertical section? Currently very short, ~0.5 seconds – do we need a minimum time spec? Making this section longer is not practical due to excessive height requirements.

(b). Is there value in keeping the diameter fixed for the entire tunnel -- no reduction sections after the mixing section?

(c). Is the 90 deg bend before the straight vertical sampling section an issue? Allow sets of 45 deg. [30 deg, 22 deg?] bends to get 90 deg? E.g., more of a curve than an elbow?

(d). Is the 30 ft. overall length ASTM limit necessary? Requiring a longer horizontal "mixing section" after the hood and before the final bend might exceed 30 ft.

(e). Flow straighteners? They may get rid of cyclonic flow but alone may not ensure good mixing.

(g). Baffles like 5G has? Other baffle designs? Concerns re: particle deposition.

3. Alternatives to pitot tubes. Assuming the tunnel design is for 500 to 800 cfm, and one recommendation is a lower velocity / longer residence time / wider duct diameter [12 to 15"] for the straight vertical sampling section, pitot tubes can't be used for velocity measurements.

- tunnel flow measurement alternatives at lower velocities - sharp edged orifice?
- use hotwire anemometer for velocity traverses instead of pitot tubes?

4. How should mixing for PM be evaluated? Mixing is very dynamic, and can change dramatically during a run. A short test is not sufficient; measurements for a full test run are needed.

(a). Use a pair of CO analyzers? Paired [dichot] TEOMs for PM?

(b). What is the worst case mixing scenario re: tunnel DF / tunnel flows / stack flows? Should labs be constrained to tunnel flows used to evaluate mixing?

(c). Should verification of mixing be required for EPA lab certifications?

Diagrams of the ASTM 2515 tunnel are included below, along with some examples of tunnels used by some EPA certified test labs.

Phil Hopke suggested these papers might inform potential issues with a 90 deg. bend just upstream of the downward vertical section used for sampling, and that CFD might be a useful tool to evaluate tunnel performance in general. If you would like a copy of any of these papers, please let me know.

Cong-A model for evaluating the particle penetration efficiency in a ninety-degree bend with a circular-cross section in laminar and turbulent flow regions_PowderTech2017 http://dx.doi.org/10.1016/j.powtec.2016.10.074

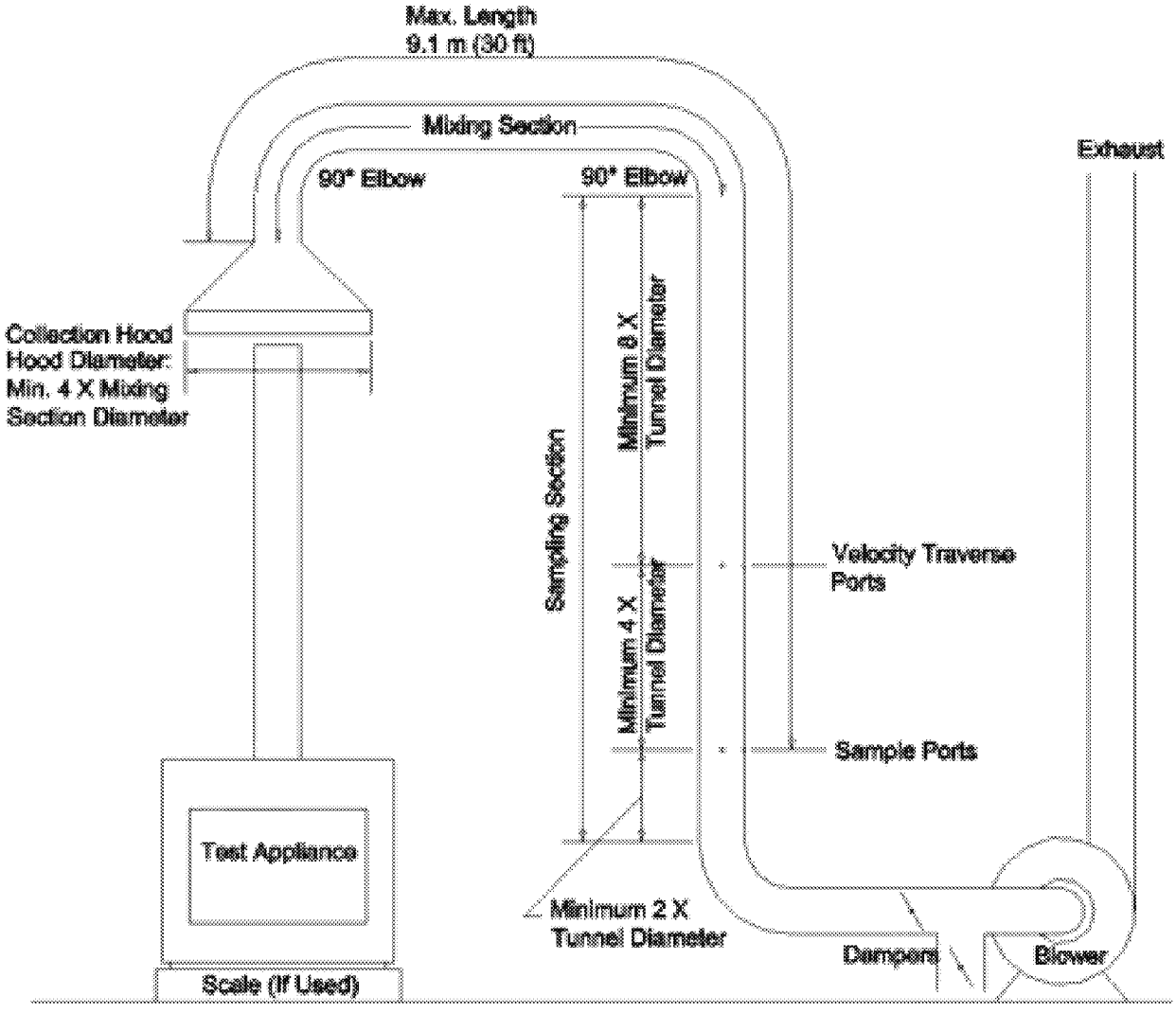
Noorani-Particle Velocity and Acceleration in Turbulent Bent Pipe Flows_FlowTurbulenceCombust2015 http://dx.doi.org/10.1007/s10494-015-9638-9

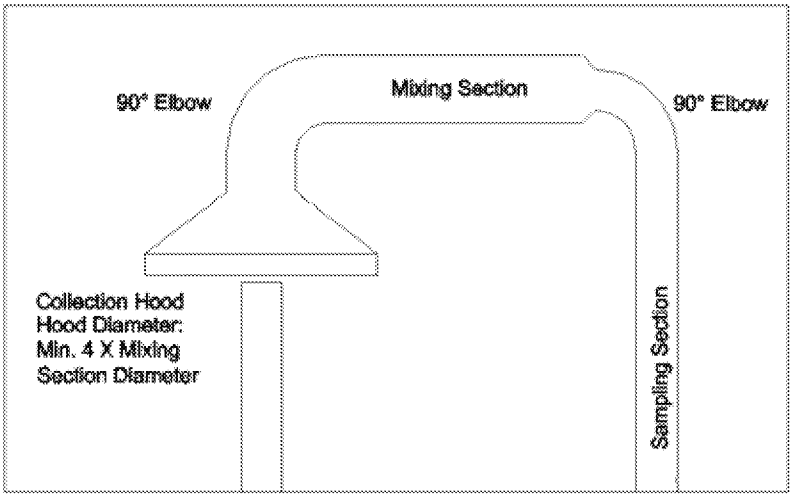
Peters-Particle Deposition in Industrial Duct Bends_AnnalsOccupationalHygiene2004 http://dx.doi.org/10.1093/annhyg/meh031 [open access]

Hellström -Turbulent pipe flow downstream of a 90 deg bend_J.FluidMech.2013 http://dx.doi.org/10.1017/jfm.2013.534

McFarland-Aerosol Deposition in Bends with Turbulent Flow_EST1997 https://pubs.acs.org/doi/abs/10.1021/es960975c [open access]

ASTM 2515 tunnel diagram:



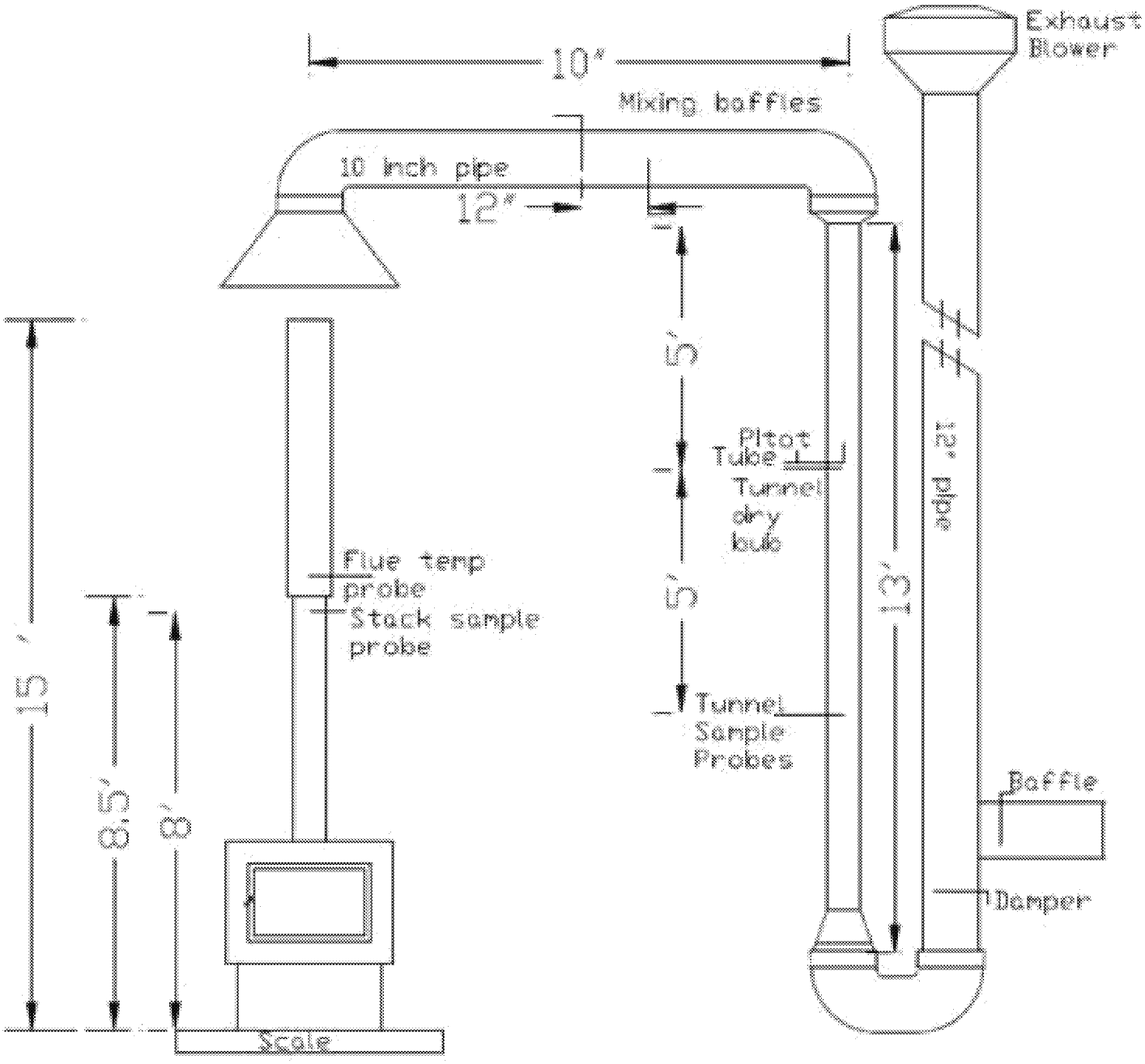


ASTM 2515 detail.

Note that there are no dimensions specified for the mixing section.

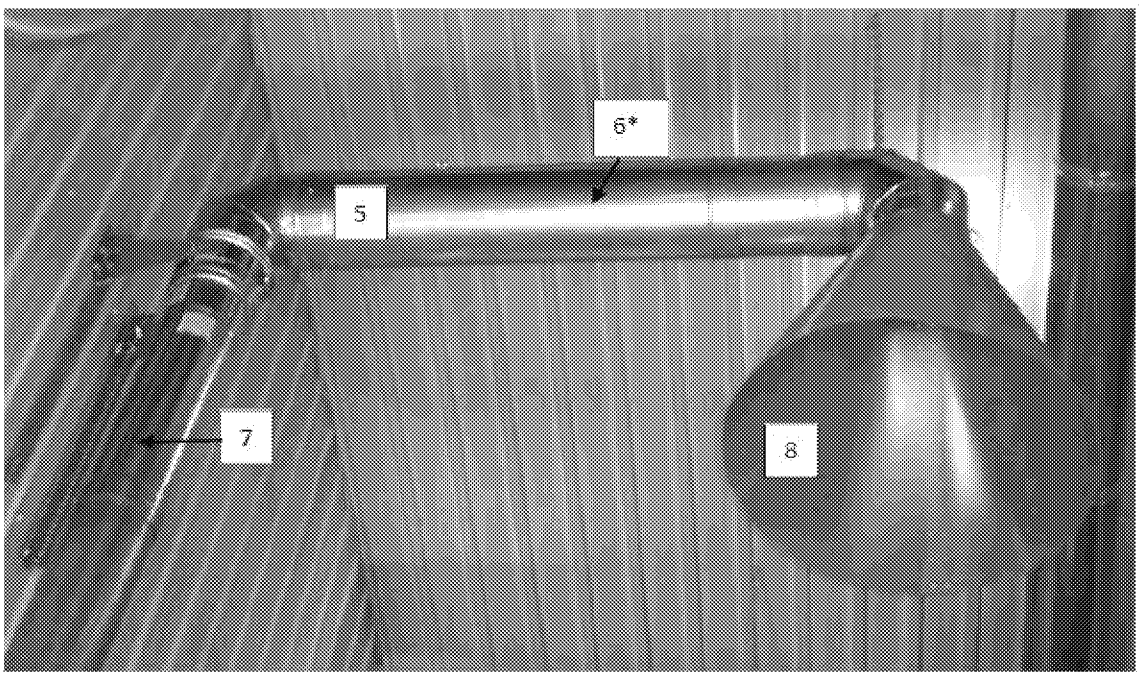
Reduction in size before elbow is not required.

Example of a non-compliant ASTM2515 tunnel from an EPA certified lab (reducer is after the elbow). The diameter of vertical sampling section is not specified; it is either 6 or 8".



ASTM Tunnel in EPA certified lab; horizontal mixing section is 12”; vertical is 8”.

Picture 2: Hood and mixing baffle



*The arrow point the deflectors inside of the pipe

5 : 8 in. dia. Stainless steel pipe

6 : Mixing baffle (2) location 1 foot between baffles

7 : 10 feet long between velocity port and upper elbow

8 : 48 in. dia. Galvanized steel smoke captures hood